Analysis: Do neonicotinoid and glyphosate pesticides threaten bees? A reassessment

In 2006, honeybees by the millions mysteriously began abandoning their colonies, leaving behind the queen bee, attended by too few, immature worker bees to sustain the colony. There was no clear explanation for this ecological disaster, especially because the hives were found to have viable brood and stored food. This phenomenon was later dubbed Colony Collapse Disorder (CCD).

Although honeybee colony numbers began to recover in 2009, according to USDA data, and subsequently stabilized, and honeybee hive numbers are now at record numbers globally, prominent environmental groups blamed the crisis on GMO crops engineered to tolerate the herbicide glyphosate (Roundup, manufactured by Monsanto, now owned by Bayer). But there was little evidence to support this claim. Activists then targeted neonicotinoid insecticides as the culprit for honeybee declines, a controversial hypothesis GLP has covered extensively.

But with the 'glyphosate trials' continuing, activists continue to hammer the glyphosate-harms-bees narrative. They have also amped up their attacks on neonicotinoids, which while not directly linked to genetically modified crops, are used extensively by conventional farmers. They base their claims on several studies suggesting that the herbicide inhibits honeybees' ability to collect the necessary resources to maintain healthy hives and boosts their risk of infection by deadly pathogens.

Alternative medicine proponent and anti-vaccine doctor Joe Mercola, who once called Bayer's purchase of Monsanto "A Match Made In Hell," wrote in September 2018 that glyphosate, besides possibly causing cancer, nutritional deficiencies and systemic toxicity in humans may also "…. kill bees by altering the bacterial composition in the bees' guts, making them more prone to fatal infections."

And Michael Balter, who was fired by *Science Magazine* in 2016, and is now allied with USRTK, an organic-industry funded anti-biotechnology group, likewise recently cited controversial studies claiming glyphosate may harm bees by "…. impeding the growth of bee larvae, diminishing bees' navigational skills …. or even disrupting their gut microorganisms…." Balter also tweeted there is a "legitimate public and scientific debate" about whether or not glyphosate is carcinogenic. He dismissed researchers and science organizations who disagree with him as industry shills, although 19 regulatory agencies around the world have issued reports concluding glyphosate is unlikely to cause cancer, and no risk-based agency concludes otherwise.

Are activists like Mercola and journalists skeptical of biotechnology such as Balter correct to link glyphosate or neonicotinoids to bee health issues? The GLP has examined that controversy in its GMO FAQ special series report: "Are GMOs and pesticides threatening bees?" We elaborate on it here so readers can evaluate the pros and cons of the ongoing indictment of glyphosate and neonicotinoids:

Are GMOs and pesticides threatening bees?

> **“The honeybee is in no way endangered. If there’s a top ten list of what’s killing honey bee colonies, I’d put pesticides at number 11.”**
> —Michael Burgett, professor emeritus of entomology at Oregon State University
> **“Scientists know that bees are dying from a variety of factors—pesticides, drought, habitat destruction, nutrition deficit, air pollution, global warming and more. Many of these causes are interrelated. The bottom line is that we know humans are largely responsible for the two most prominent causes: pesticides and habitat loss.”**
> —Greenpeace

At a Glance

In 2006, honeybees by the millions mysteriously began abandoning their colonies, leaving behind the queen bee, attended by too few, immature worker bees to sustain the colony. There was no clear explanation for what would have been an ecological disaster if it continued and spread around the world, especially because the colonies were found to have viable brood and stored food. This phenomenon was later dubbed Colony Collapse Disorder (CCD).

Prominent environmental groups first blamed the crisis on genetically engineered (GMO) crops and the herbicide Roundup (manufactured by Monsanto, but also sold in generic form as glyphosate), but there was no evidence to support this claim. After not getting traction for this assertion, they targeted a relatively new class of insecticides introduced in the mid 1990s known for their low toxicity and sustainability advantages: Neonicotinoids (aka neonics).

The CCD crisis, centered mainly in California, faded over the next few years, without scientists ever determining its definitive cause. But environmental advocacy organizations built on this temporary 'crisis' to call attention to higher-than average overwinter bee death rates that temporarily ensured after the CCD crisis. A slew of laboratory studies suggested that neonics could be a factor. Banning "bee-killing" neonic pesticides, it was said, was essential to sustain world food production and prevent an irreversible situation that some in the media dubbed a coming "beepocalypse."

Most entomologists, rather, believed bee health problems reflect a slew of issues, primarily the impact of the *Varroa destructor* mite, recognized as the greatest single scourge of honeybees, the increased use of miticides and the fact that beekeepers in the US transport honeybee colonies across the continent, annually and seasonally, which weakens bees and exacerbates ongoing health issues.

In 2013, in response to escalating advocacy campaigns and media stories, and fueled by findings in lab studies, the European Union placed a moratorium on three neonicotinoids. France banned two additional neonics. Canada has announced plans to phase out another. Despite these moves to restrict neonics, the hive numbers of honeybees have improved considerably in places where a ban was not in place, including the US and Canada, where they are at record levels, and are flourishing in Australia, where neonics are widely used. Global hive numbers are at record levels. Even the Sierra Club now says that honeybees are not in crisis.

The Environmental Protection Agency and the US Department of Agriculture and studies from agencies in Canada and Australia, where neonicotinoids are also widely used, have reached the consensus conclusion that while bees do face serious health challenges, particularly from mite infestations and a gut fungus called *nosema ceranae*, they are not in crisis and are not facing extinction due to the use of "toxic" pesticides. Scientists familiar with extensive field studies, which contradict many less state-of-the-art lab research, say pesticides are a limited threat to managed honeybees, bumble bees and native populations. There is no impending 'bee-Armageddon'.

Science and Politics

First introduced in 1995, neonicotinoids are a class of insecticides popular in the US, Australia, Europe and elsewhere to control insect infestations of corn, soy, cotton and canola (aka oilseed rape). They also are widely used to combat pest devastation of vegetable crops, rice, cotton, melons, grapes and berries, and orchard crops, and are considered critical in combating the lethal 'citrus greening' disease spreading from already-devastated Florida to Texas and California. Seed coatings for row crops account for the

largest volume of neonic usage by far.

Applied to the soil, sprayed on the crop or, most commonly, used as a seed treatment, neonics reach the insect pests that feed by chewing or sucking crop plants. Seed coatings for row crops account for the largest volume of neonic usage by far. Seed treatments also lower the amount of the *pre-neonic, older, more toxic, spray-applied pesticides* that previously were sprayed 10 to 20 fold, decreasing the need for open spraying of the plant, a major sustainability benefit. Scientists, farmers and many environmentalists, at least initially, applauded their development as neonics proved effective against common plant pests but were seen as relatively harmless to many beneficial insects because of their systemic action: the insecticide is taken up into plant tissue where it consequently controls only the pests that actually feed on the crop.

The mode of action of neonics is different from the sprays they replaced: Organophosphate pesticides,

which are known to kill bees and wildlife (and have been linked to health problems in agricultural workers); and a class of natural insecticides known as pyrethrins, and their synthetic analogs, pyrethroids, which are deadly to bees and many beneficial insects, and known to kill mammals, including dogs and cats. By contrast, neonicotinoids are benign to mammalian physiology; they are a key ingredient in several long-lasting flea and tick remedies for dogs and cats that owners apply monthly directly to their pets' skin without any harmful effect. But because of their because of their systemic uptake in plants, worries persisted.

Neonicotinoid usage surged in the early 2000s with no appreciable effect on either wild bees or honeybees. Yet the unrelated CCD crisis in 2006 fueled public concern about neonics and attracted the attention of anti-biotechnology and environmental activists. The public fervor escalated, as symbolized by the 2013 Time Magazine cover, "A World Without Bees," and persists today, embracing concerns about other types of bees, beneficial insects and even birds. The situation was dire, they environmental advocacy groups alleged, because bees are an important pollinator, responsible for "one in every three bites of food we eat (a claim disputed at the time by most scientists as exaggerated).

Although the problems facing honeybees moderated, overwinter losses remained above historical norms for the next several years. Activists and some scientists blamed neonics for these declines, although there were no clear links. The assertions were mostly buttressed by a slew of worrisome laboratory studies, some funded by environmental groups. The studies were covered intensively by the media, often framed in apocalyptic terms, stirring public and political debates. In 2013, in response to escalating advocacy campaigns and media stories, and fueled by findings in lab studies, the EU placed a moratorium on three most widely-used neonicotinoids, forbidding their use on bee-attractive flowering crops.

What evidence supports claims that pollinators are threatened? Neonicotinoids were suspected to pose an a degree of risk to bees, partly because of their systemic uptake in plants. Numerous "caged bee" studies indeed have shown that that "sublethal" exposure to neonics weakens the bees' immune systems and interferes with their foraging behavior, boosting their vulnerability to deadly infections and sabotaging their ability to feed themselves. In one widely reported 2015 real world study that heightened concerns, showed that one neonic, clothianidin**,** when used in combination with pyrethroid in a flowering crop could have serious consequences for wild bees. In a contradictory and unexplained finding, the study found no effect on honeybees, raising concerns among critics that it was a one-off.

After surveying some 1500 studies, the European Food Safety Authority (EFSA) concluded in a 2018 report that some honeybees and managed bumblebees faced "high risk" from three neonicotinoid insecticides, although the EFSA's interpretations of the studies were challenged by numerous scientists skeptical of the conclusion. That finding led that EU its ban to make its ban permanent in 2018. France and Canada enacted restrictions on certain uses of these insecticides in 2018 and 2019.

Many scientists, particularly entomologists, remained skeptical of the conclusions and critical of the bans on neonicotinoids, which many farmers testified was critical for their economic survival. Neonics are widely used on corn, oilseed rape and sunflower crops. US economists estimated in 2017 that that a nationwide ban on neonics would cost North American consumers in excess of $4.5 billion annually in

higher food prices. An industry-funded study in Europe estimated that a ban on just neonicotinoid, oilseed rape, would cost the industry more than $1.2 billion. The study also claimed an 'unintended consequences' effect: shifting oilseed rape production outside the EU triggered a conversion of more than 1.2 million acres of grass land and natural habitats to arable land equaling the loss of of more than 750,000 acres a of biodiversity-rich rainforest. Despite these warnings and the scanty and sometimes contradictory research, the bans in Europe have been fully implemented and states in the US are mulling restrictions.

How reliable are lab studies on bees?

The lab studies of the impact of neonicotinoids share a problem: Exposing bees to neonics in a closed environment does not replicate what happens in real life; it doesn't tell us much about how seed treatments affect bee colonies in their natural environment. The vast majority of the laboratory research are so-called "caged bee" studies: experiments in which individual bees are exposed to some level of neonic pesticides and then examined for an adverse effect. Some such studies, for instance, have shown that "sublethal" exposure to neonics can weaken honeybees' immune systems and/or interfere with their foraging behavior, boosting their vulnerability to deadly infections and sabotaging their ability to feed themselves.

The problem with most laboratory 'caged bee' studies is that they invariably over-dose the bees — even when low, purportedly 'field realistic' doses are applied. Lab studies also don't evaluate bees in the context of their community. The beehive constitutes what amounts to a super-organism. Through the collective action of its tens of thousands of specialized members, it is capable of achieving things like significant detoxification of the hive and, hence, protection of its members that no individual bee could ever do alone, whether in a laboratory or in nature.

In contrast, the clearest, most accurate and most reliable picture of neonics' effects on honeybees is obtained from large-scale field studies under conditions approximating as closely as possible the real-world conditions under which colonies live, forage, reproduce, store food and over-winter. They are, consequently, very costly — tens or hundreds of times more expensive than laboratory 'caged bee' studies — and so there there far fewer of them. Thirteen such studies published in the last decade have examined how honeybees or bumble bees foraging in neonics-treated crops fared. All concluded that there was little to no observable adverse effect on bees at the colony level from field-realistic exposure to neonicotinoids-treated crops. In other words, because of the detoxifying and new brood producing capabilities in bee hives that overpower potential negative impacts on individual insects, low-level neonic exposure of individual bees is unlikely to have a serious deleterious effect on overall colony health.

Impact of glyphosate on bees

Some environmentalists have also argued that the herbicide glyphosate (Monsanto's Roundup now made by Bayer) kills bees or threatens their ability to collect the necessary resources to maintain healthy hives. A 2013 study which showed that caged bees fed glyphosate experienced reduced sensitivity to nectar

reward and impaired associative learning, the anti-crop biotehnology website Natural News claimed: “[A] groundbreaking study shows that Roundup causes honeybees to starve.” That was an overstatement, however. The study authors qualified their findings, noting that “….no effect on foraging-related behavior was found.”

honey bees fungicides

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There are numerous issues with these claimed findings. Critics of the study have pointed out that bees don’t consume large doses of glyphosate on agricultural fields, a fact that severely limits the significance of the research.

Glyphosate is also sometimes paired with a pre-emergent(before seeds germinate and before insects are present in the fields. I a 2014 study, scientists exposed honeybees to glyphosate “at realistic worst-case exposure rates” and found:

> ….[T]here were no significant effects from glyphosate observed in brood survival, development, and mean pupal weight. Additionally, there were no biologically significant levels of adult mortality observed in any glyphosate treatment group.

USDA researchers conducted a field study in 2015 to see how honeybees reacted to 40 pesticides commonly used in agriculture. Of the chemicals tested, glyphosate was the least toxic, with the researchers concluding that it is "…relatively safe to foraging bees because [it] may kill less [than] 1% [of] bees at the field use rate."

The glyphosate-bee death hypothesis got a boost in September 2018, when a study in the Proceedings of the National Academy of Sciences asserted that glyphosate exposure harmed the gut health of honeybees and increased their "susceptibility to infection by opportunistic pathogens." Environmental websites promoted the findings with headlines such as: "Glyphosate could be factor in bee decline, study warns."

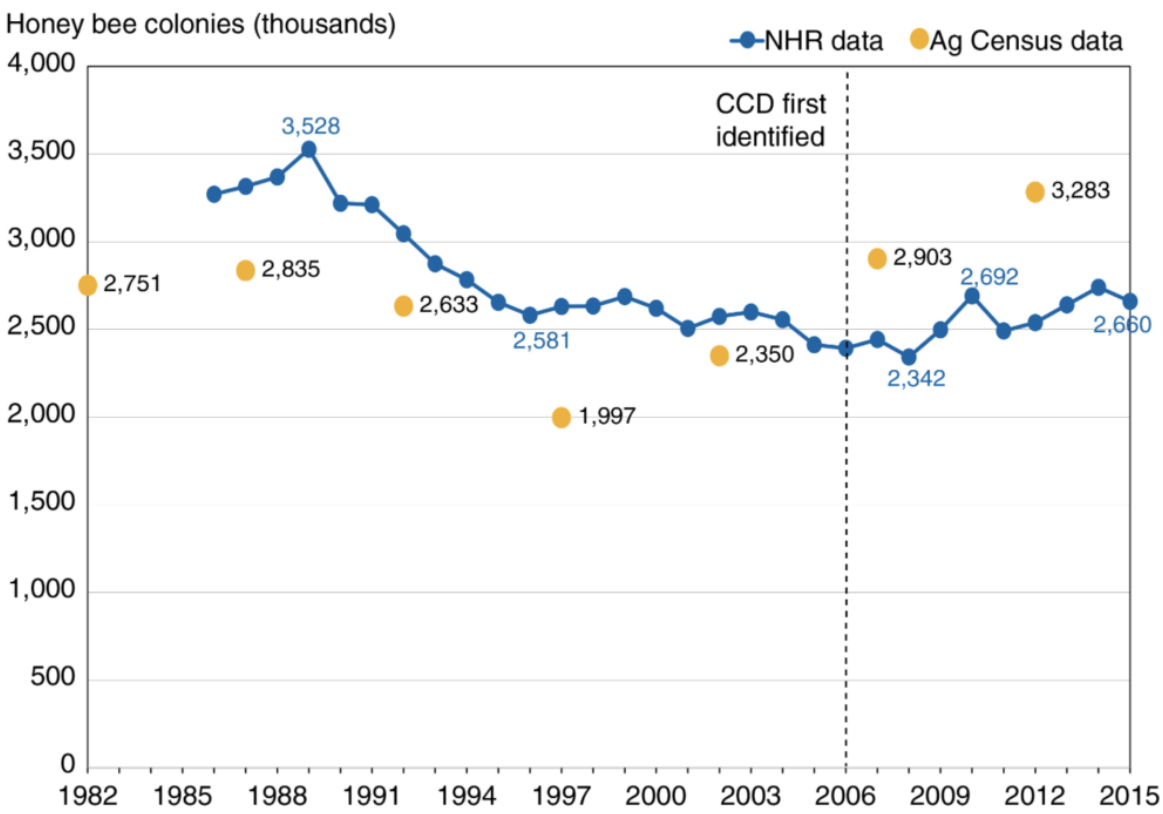
Experts noted this study suffered from some serious limitations. The researchers found that the health of bees was worse when they were exposed to lower doses of the herbicide. Such a result violates the bedrock principle of toxicology that a chemical can be harmless or even beneficial at low concentrations but poisonous at higher ones; the dose makes the poison. Other flaws in the study were serious enough for researchers to doubt its validity, pending further research.

The overwhelming preponderance of honeybees are not 'wild' but are raised by beekeepers, rather like 'livestock'. Consequently, their population numbers aren't purely at the mercy of environmental factors like parasites, diseases, temperature, rainfall, weather, pesticides or other contaminants that bees may encounter. Colony numbers, although affected by these factors, are essentially determined by how many colonies beekeepers, in the aggregate, determine is profitable to cultivate and maintain.

Increase in bee populations

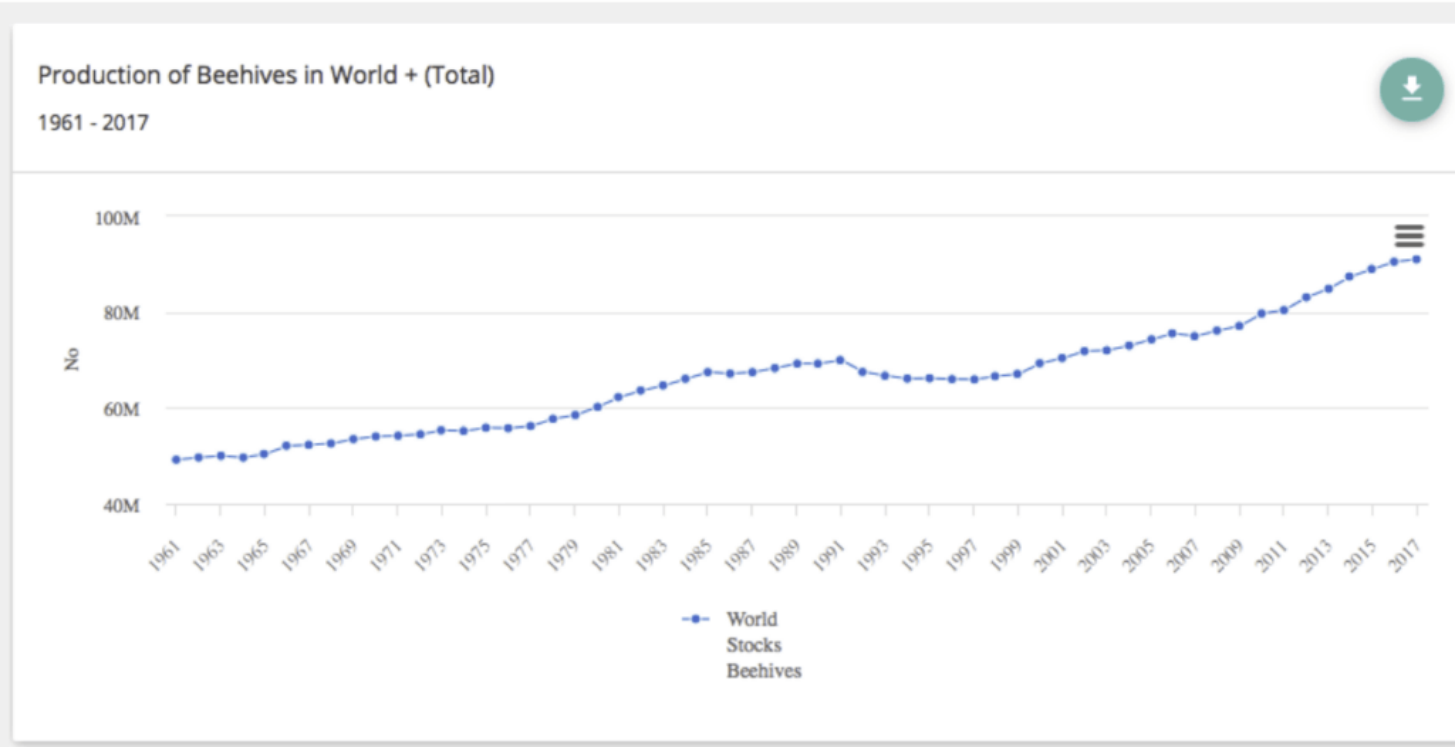
The data clearly show bees are in no danger of facing a catastrophic die-off — the common meme over the past decade. October 2018 statistics from the United States Department of Agriculture (USDA) show that honeybee populations are stable and may even be growing. The 1988 'highpoint' of this graph follows closely the 1987 arrival of the *Varroa destructor* parasite in the United States from the Far East — an event that promptly produced precipitous decline in US honeybee colonies until beekeepers developed management techniques to stabilize the situation over the ensuing decade. After the CCD outbreak in 2006, between 2007 and 2013, winter colony loss rates averaged 30 percent, which is approximately double the loss rate previously thought to be normal. Elevated winter colony losses, however, have not resulted in enduring declines in colony numbers. Instead, the number of honey bee colonies is either stable or growing depending on the dataset being considered. This chart shows trends through 2015; the number of colonies has steadily increased since then.

Honey bee colony levels have remained stable despite elevated loss rates



Notes: CCD = Colony Collapse Disorder. NHR = National Honey Report.
Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service Agriculture Census data and USDA, Agricultural Marketing Service National Honey Report data.

The USDA data confirmed research that showed that honeybee populations in the US, Canada and Europe have remained stable or increased since neonics were introduced in in the mid-1990s. In western Canada, colonies are thriving while foraging on 21-million-acres, almost 100% neonic-treated, pollen- and nectar-rich canola crop. Populations in Australia, where neonics are heavily used and there are no *Varroa* mites, haven't experienced declines over the same time period. As the Washington Post reported in 2015 in "Call Off the Bee-pocalypse: U.S. Honeybee Colonies Hit a 20-Year High" and "Believe It or Not, the Bees Are Doing Just Fine", global honeybee hive numbers have risen to record levels.



© FAO, Production of Beehives world total 1961-2017, Web address: http://www.fao.org/faostat/en/#data/QA/visualize, Accessed: 14/01/19

It is normal for beekeepers to lose a percentage of their hives every year, especially in the winter, due to weather, disease or the exhaustion of stored food supplies. It is also normal for the number of hives to fluctuate annually for market reasons. However, misrepresentations of *overwinter* bee losses, or the adding together of winter and summer loss numbers, makes it seem as if the mid-2000s CCD event is ongoing, when it is not.

None of this is to suggest that bee health problems are not real. Honeybees and perhaps bumble bees, mostly wild native bees, face health threats that are cause for worry, and they need to be addressed. There are increasing health pressures as livestock honeybees are trucked around North America, stressing bee colonies. The greatest threat to bee health, according to the USDA, is the *Varroa destructor* mite, which the agency calls:

> … [T]he single most detrimental pest of honey bees. Since the 1980s, honey bees and beekeepers have had to deal with a host of new pathogens from deformed wing virus to nosema fungi, new parasites such as Varroa mites, pests like small hive beetles, nutrition problems from lack of diversity or availability in pollen and nectar sources, and possible sublethal effects of pesticides. These problems, many of which honey bees might be able to

survive if each were the only one, are often hitting in a wide variety of combinations, and weakening and killing honey bee colonies. CCD may even be a result of a combination of two or more of these factors and not necessarily the same factors in the same order in every instance.

figure

The parasite poses unique challenges to beekeepers and scientists. It sucks the bees' hemolymph' (blood-equivalent), compromises the immune system, vectors viruses into bee colonies and attacks the honeybee's fat body, a structure that plays a vital role in its ability to metabolize food, causing the bee to be chronically undernourished until it dies. Worse, *Varroa* mites rapidly develop resistance to different treatments, making control difficult.

The Takeaway

There is no honey 'beepocalypse', and there never was. The phenomenon of CCD — Colony Collapse Disorder — that was causing such a scare as recently as 2013 is similar to historical phenomena over many centuries and appears wholly unrelated to pesticides. It has come and gone as mysteriously this time as it has on every previous occasion in history.

Bees are facing health challenges. Some claim that bees are not threatened, noting that hive numbers are up, implying that all bee problems are behind us. That's not accurate. Relying solely on hive numbers, instead of percent losses, or actual bee numbers, can be misleading. Splitting a hive in two and inserting a new queen is not an indication of an improvement in bee health or numbers.

The honeybee industry is coping with the situation although some exacerbating health threats such as the transportation of bees across North America will remain, challenging bee health. A small number of wild bumblebee species also may be in decline, but there is so far no clear indication of a crisis. The status of so many species is unknown and little tracking data exist.

The causes of the health challenges are varied, although there is general agreement that the Varroa mite has for decades posed the greatest challenge. The research available shows that pesticides are not a major driver of those problems. While pesticides can be harmful to bees exposed to large doses, studies reproducing real-world conditions do not show that pesticides and the GMO crops they're often paired with are driving bees toward extinction, as some environmentalists claim.

Numerous laboratory studies have shown that neonics can cause bee disorientation. But that is true about all insecticides. The results of laboratory 'caged bee' studies — though abundant (because they are relatively cheap and easy to do) — are an unreliable indicator of neonics' effects on honeybees and their colonies precisely because they do not factor in the dynamic ability of bee colonies to detoxify themselves and of bees to rapidly metabolize pesticides and to reproduce.

Large-scale field studies in which honeybees and bumble bees encounter field-realistic doses of neonics on a sustained basis are by far the most reliable indicators of neonics' effects on bees. Such studies consistently show no observable adverse effects at the colony level from field-realistic exposures of honey bees to neonicotinids.

Chemicals are necessary in farming to control pests. Scientists say it's important to weigh the benefits of each chemical against its potential threats, and consider what the impact would be of replacement chemicals. The EPA has explained that while thirty-six replacement pesticides for neonics are presently registered for use in the US, "All can potentially cause acute and subacute toxicity" in bees.

Europe's neonics ban has had serious economic and environmental repercussions for farmers and proved harmful to bees because of the swapping in of more toxic chemicals. Sugar beet growers have said there are "no sustainable alternatives" to neonicotinoids. The UK government has acknowledged that farmers have switched back to insecticide sprays, such as organophosphates, that are more toxic to bees and humans, boosting their overall chemical use in the process. Substitute pesticides also don't work as well. For example, in May, 2019, the UK had to issue an emergency use exemption for banned neonicotinoid insecticide to prevent virus spread in sugar beets. Following the ban, yields dropped dramatically in all crops in Europe previously treated with neonics. A 2017 study on one crop, oilseed rape (canola), indicated the ban has cut quality yield by more than 6 percent and cost farmers more than $1 billion.

That said, neonicotinoids alone cannot prevent all insect infestations. Beekeepers have warned that common plant pests, no longer controlled by neonics, are destroying an increasing volume of acres of flowering crops that bees forage in, thus posing a bigger threat to these valuable pollinators than insecticides ever did. Alternative pesticides need to be developed.

Although bee health problems are a genuine concern, the scientific consensus is that blaming GMO crops, glyphosate or one class of insecticides, neonicotinoids, oversimplifies a complex problem for which there is no easy solution, as substitutes are either as effective or as safe. Experts also note that bans could spur a return to pest controls that are demonstrably more harmful to beneficial insects and mammals — a situation already unfolding in Europe.

“I am not convinced that neonics are a major driver of colony loss,” said University of Maryland’s Dennis vanEnglesdorp, the entomologist who coined the term “Colony Collapse Disorder.”

The GMO FAQ and additional resources are available here: “Are GMOs and pesticides threatening bees?”

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